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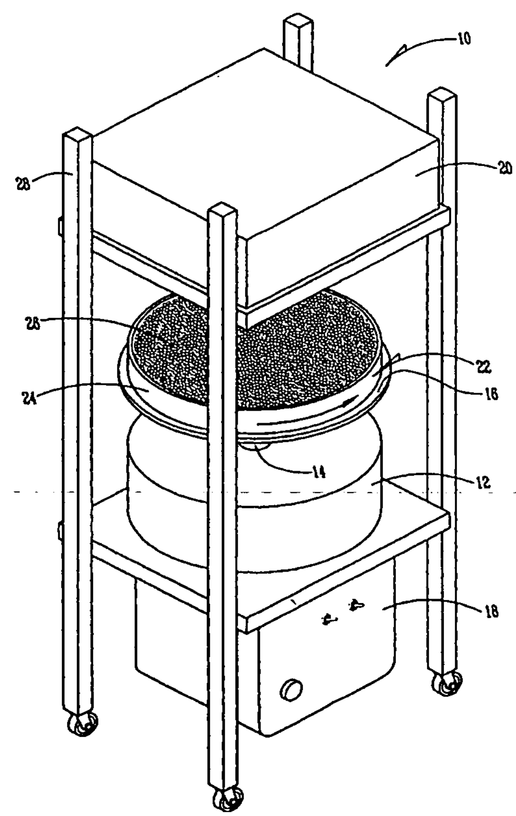
(54) Title: SPECIMEN TURNTABLE AND NEAR INFRARED (NIR) SPECTROMETER FOR REAL TIME GRAIN AND FORAGE ANALYSIS

(57) Abstract

An apparatus and method for combining NIR spectroscopy (20) with a rotatable specimen turntable (16) for measuring major constituents of harvested product (26) in real time. The monochromator includes a fixed diffraction grating (38) and a photodiode collector (40) comprised of a plurality of photodiodes (54). A radiation source (44) irradiates a product sample rotating on the turntable, and the reflected radiation is transmitted to the diffraction grating. By analyzing the intensities and wavelengths of the reflected radiation at the photodiode collector, the presence and amount of constituents or characteristics of the harvested product can be determined.



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TITLE:

SPECIMEN TURNTABLE AND NEAR INFRARED (NIR) SPECTROMETER FOR REAL TIME GRAIN AND FORAGE ANALYSIS

BACKGROUND OF THE INVENTION

Field Of The Invention

The present invention relates to an instrument for measuring quality parameters or traits of harvested agricultural products. More particularly, though not exclusively, the present invention relates to a specimen turntable and a near infrared spectrometer, and a method of using the instrument, for real time product analysis.

Problems In The Art

In the field of agriculture, it is important to analyze agricultural products such as grain, silage or forage to determine quality parameters or traits in the products. This is particularly important in breeding programs.

One prior art method of analyzing grain and other agricultural products uses near infrared spectroscopy (NIR). NIR is a well established technique for detecting both chemical and physical properties of various materials. NIR provides an accurate and inexpensive method to analyze agricultural materials such as grain, silage or forage. Major constituents that can be detected by using NIR include moisture, protein, oil, starch, amino acids, extractable starch, density, test weight, cell wall content, and any other constituents or properties that are of commercial value. Other measurable parameters include dry matter (DM), crude fiber(CF), cellulase whole plant digestibilities (IVDC), pH, fermentation acids and crude protein (CP). Prior art analysis techniques use dried and ground products, rather than fresh undried products which may be fermented. Fermented materials contain highly volatile constituents being lost through drying and thus leads to erroneous data.

Analysis of grain, silage and forage parameters is currently started by drying facilities at labs or stations. All dried samples, where quality parameters are requested, are sent to the lab, ground to a small particle size and then analyzed using classical dry NIRs. These conventional NIR analysis techniques are very time consuming and tedious,

particularly in view of the drying and grinding requirement and, therefore, cannot be applied to all stages of product development.

The ability to measure the parameters or characteristics using intact product at the farm, field, silo or storage station provides many advantages. These advantages include less drying and lab costs to analyze the desired qualities; earlier selection of product traits; superior selection, because more germplasms may be screened; more efficient planning and usage of winter nurseries due to quicker results; on site analysis provides quick and reliable service to product seed customers; and more traits like pH and volatile fatty acids can be determined, which is not the case with dried material.

There are various types of devices used for NIR. In general, these devices include light sensors in conjunction with light sources which are used with any number of measuring devices. In optical spectrometers, the incident light from a light source is passed through a monochromator, which can be a filter or set of filters, a diffraction grating, or a prism whose angular displacement relative to the incoming light can be closely correlated with the single wavelength, or narrow band of wavelengths which are sent on to the light sensor. The light sensor is selected so that its spectral responses match the wavelength of interest. The angular motion of the prism or diffraction grating can be mechanized so that a given spectrum is scanned at a known rate over a known time interval. Such a device is referred to as a scanning spectrometer. The wavelength of an observed peak can then be determined from the time counted from the start of a scan. Spectrometers may also be referred to as spectrophotometers when their spectral range extends between ultraviolet to infrared. With this type of NIR, the ground sample is irradiated with near infrared light. The reflected radiation is detected at narrow band wavelengths in the NIR spectrum to obtain raw reflectance data of the sample. The data can be used to provide predictions of the content of constituents or parameters of the grain samples.

Other prior art systems use scanning or oscillating spectrophotometric instruments. In such an instrument, a photo detector detects light energy which is scanned through a spectrum at a rapid rate. Such an instrument employs an optical grating which receives light through an entrance slit and disperses the light into a spectrum directed toward an exit slit. The optical grating is oscillated in order to rapidly scan the light transmitted through

the exist slit through the spectrum dispersed by the grating. Another prior art instrument uses filters which are tilted as they pass through a light beam to scan the transmitted light through a spectrum. Either type of instrument, the oscillating optical grating or the tilt filter type can be operated over a spectrum covering near infrared to analyze agricultural products such as grain or forage. Using an oscillating grating or tilting filter type of instrument, the user can measure the reflectivity of the sample at narrow wavelength increments to determine the constituent contents of a grain sample. To use an oscillating grating or tilting filter instrument, the narrow bandwidth light is transmitted through the exit slit used to illuminate the grain sample. The light reflected from the sample is detected by photo detectors and the resulting photo detector signal is used to determine the constituent contents of the sample. As the grating oscillates, the center frequency of the light that irradiates the sample is swept through the NIR spectrum. Light from the diffraction grating that is reflected by the sample is detected by the photo detector. As an alternative to detecting the energy reflected from the sample, the energy may be transmitted through the sample and detected after being transmitted through the sample. In addition, instead of irradiating the sample with the output from the spectrophotometer, the sample can be irradiated with constant wideband light and a reflected light being applied to the spectrophotometer.

If a grain sample is not ground, the light absorbency and reflectance varies considerably from sample to sample. This variation is caused by light scatter from the whole particle, like grain kernels, and by the nonlinear surface reflectance effects. This variation makes it difficult to obtain accurate measurements from whole grain samples. Similar problems are encountered with forage samples, but are even more pronounced with corn forage.

The spectrometers discussed above have several disadvantages. The spectrometers discussed are only suitable for use in a laboratory. Prior art methods of grain and forage analysis have a major disadvantage resulting from the large amount of sample handling. The samples must be harvested, collected, bagged, labeled, dried, sent to the NIR lab, ground and analyzed for constituent analysis. This excessive sample handling adds both cost and time to the analysis. Thus, a need exists for an NIR instrument for analyzing grain and forage samples at a site such as the farm, field, silo, elevator or storage station. Such a

system reduces the cost and time of the analysis. Such a system provides plant breeders and farmers with real time information and also enhances product development through high plot screening numbers which would help develop products more rapidly.

Objectives Of The Invention

A primary objective of the present invention is the provision of a method and apparatus for measuring constituents or parameters of harvested agricultural products at a convenient site, such as the farm, field, silo or storage station, which overcomes problems found in the prior art.

Another objective of the present invention is the provision of an apparatus and method of measuring the constituents of agricultural products which senses the reflectance of a rotating sample to improve spectral reflectance and increase the sample surface area.

A further objective of the present invention is the provision of a method and apparatus for measuring constituents of agricultural products which is capable of accurately measuring the constituents in a short time period.

Another objective of the present invention is the provision of an apparatus and method of measuring the constituents of agricultural products using the reflectance of radiation from the agricultural product.

Still another objective of the present invention is the provision of an apparatus and method of measuring the constituents of agricultural products which measures the constituents in real time and stores the measurements for later use.

These as well as other objectives and advantages of the present invention will become apparent from the following specification and claims.

SUMMARY OF THE INVENTION

The present invention relates to a method and apparatus for measuring constituents of harvested agricultural products at a convenient site, such as a farm, field, silo or storage facility. The invention uses near infrared spectoscopy equipment to sense reflection from a specimen on a rotating turntable. A radiation source is used to irradiate a product sample while the reflected radiation is collected and measured with a sensor located within, near, or adjacent to the turntable. In the preferred embodiment, a monochromator includes a

diffraction grating or its equivalent which spreads the reflected light over a desired wavelength range over a photodiode collector which is comprised of a plurality of photodetectors. By analyzing the intensities of the reflected radiation, various constituents or parameters of the product can be determined.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a perspective view of the specimen turntable and NIR instrument of the present invention.

Figure 2 is a block diagram of the NIR used in the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The present invention will be described as it applies to its preferred embodiment. It is not intended that the present invention be limited to the described embodiment. It is intended that the invention cover all alternatives, modifications, and equivalences which may be included within the spirit and scope of the invention.

With reference to the drawings, the measuring instrument of the present invention is generally designated by the reference 10. The instrument includes a variable speed motor 12 with an output shaft 14, and a turntable 16 secured to the output shaft 14. A control panel 18 is provided for controlling the operation of the motor 12, including the speed thereof.

An NIR spectrometer 20 is mounted above the turntable 16. The structure and components of the spectrometer 20 are conventional and do not form a part of the present invention.

One of a plurality of interchangeable trays or containers 22 are removably securable to the turntable 16. Each tray 22 has an outer parameter wall 24, such that the tray can hold a product specimen to be analyzed. The height of the wall 24 on the different trays 22 varies so that different volumes of grain, silage, and forage can be held in the various trays. The trays 22 are mounted to the turntable 16 using any conventional means.

In operation, one of the trays 22 is loaded with the product so as to present a specimen sample 26 to the spectrometer 20. The motor 12 is actuated so as to rotate the

turntable 16 and the attached tray 22 at a constant speed. The spectrometer 20 is activated, such that the complete surface area of the specimen sample 26 is illuminated.

The rotating specimen sample 26 provides analysis of an average surface. Preferably, the analysis time is approximately 10 seconds, but may range from 5 seconds - 60 seconds, without losing accuracy and precision. The increased sample surface area minimizes analysis fluctuations from individual product kernels or pieces.

The motor 12 and spectrometer 20 are shown to be mounted in a frame 28 such that the instrument 10 is portable. Thus, analysis of fresh product may be conducted at the farm, field, silo or storage station.

Figure 2 is a block diagram showing the components of the spectrometer 20. A monochromator 32 is connected to a fiber optic cable 34. The other end of the fiber optic cable 34 is connected to a sensor head 36. Preferably, the area around the sensor head 36 is enclosed to limit the amount of stray light which effects the performance of the sensor head 36.

The monochromator 32 used with the present invention includes a fixed diffraction grating 38 and a photodiode array 40. It is important to note that because the photodiode array 40 is used, the monochromator 32 includes no moving optical parts. This is desired in order to withstand any vibrations present from the rotating turntable or during transportation of the instrument and to be independent from the speed of the turntable. The photodiode array 40 also greatly increases the speed at which a sample can be analyzed since the entire desired spectrum of reflected light is transmitted at once, rather than scanning and transmitting one range at a time. The monochromator 32 is connected to a sensor head 36 by the bundle of fiber optic cables 34. While the fiber optic cable 34 could take on many forms, preferably the cable is comprised of 25 individual fiber optic strands.

The sensor head 36 is comprised of a housing 42 which encloses a lamp 44 and a sensor 46. The sensor 46 could take on may forms, but preferably is simply comprised of the ends of the fiber optic strands of the fiber optic cable 34. The lamp is powered by a power source 48 which is provided by the monochromator 32. The power source is connected to the lamp 44 by a power cable 50 which is preferably bundled with the fiber optic cable 34 to reduce the number of cables between the sensor head 36 and the monochromator 32. The lamp 44 is preferably a halogen lamp which provides a wide

spectrum of radiation including radiation in the desired bandwidth, 400 to 2500 nanometers (nm). The lamp 44 is aimed at a desired angle towards the samples (discussed below).

Figure 2 also shows a white reference tile 58. The white reference tile 58 has a known reflectance and therefore can be used to calibrate the present invention. For the purposes of this description, the term "calibration" does not mean finding a correlation between optical densities and constituent percentage, but rather means to correct for instrument response variations by baseline correction. The light sensor 46 is also positioned at a desired location relative to the sample 26 and lamp 44. When the lamp 44 irradiates the sample with light, some of the radiation is reflected off the sample toward the sensor 46. The reflected light is transmitted through the fiber optic cable 34 to the diffraction grating 38 in the monochromator 32. The diffraction grating scatters the light over an infinite number of paths represented by lines 52. For example, the photodiode array 40 includes e.g. 512 photo detectors 54 which are disposed along the photodiode array 40 (for purposes of clarity in the drawings, all 512 photo detectors 54 are not shown). Each photo detector 54 will receive light from the diffraction grating over just a small range of wavelengths. The diffraction grating 38 and photo detectors 54 are arranged in the monochromator 32 so that light with a spectral range, for example 400 through 1700 nanometers, is distributed along the array 40. It can be seen that by using a photodiode array with 512 photo detectors 54, the "scanning" time goes down by a factor of 512 compared to the prior art scanning spectrometer. The photodiode array 40 is connected to a proccssor 56 which collects data from the photodiode array 40 and stores and analyzes the data.

The present invention improves on accuracy and speed over the prior art. To help improve accuracy of the system, the sample presentation is made constant and repeatable. This provides consistent results. The samples are sensed in the same way and in the same location for each successive sample. Also, sensing the samples as the sample is rotating improves the accuracy and reliability since an "average" sample is taken over a larger surface area, rather than looking at still individual particles which have surfaces that vary from one part of the particle to the other. Since the samples can be analyzed at a high rate of speed, the processor can average a number of readings to obtain a consistent result for each sample. For example, if the monochromator outputs spectrum data every 34 msec,

then the processor can average 100 successive spectrums together and output a more reliable and stable spectrum every 3.4 seconds.

The present invention operates as follows. As the sample rotates past the sensor head 36, light from lamp 44 is irradiated on the sample with some of the light reflecting off the sample to the sensor 46. The reflected light is transmitted through the fiber optic bundle 34 to a diffraction grating 38 in the monochromator 32. The diffraction grating 38 spreads the reflected light over the photodiode array 40 in a spectrum ranging from, for example 400 nanometers to 1700 nm in wavelength. The processor 56 is connected to the photodiode array and collects data relating to the strength of radiation at each individual photodiode 54. By analyzing the strength of the radiation at each photodiode 54, the processor can determine the amount of constituents in the sample. For example, if the radiation strength at a certain photodiode is relatively low, then it can be determined that the sample has absorbed an amount of radiation at that wavelength. By knowing what certain substances absorb or reflect, it can be determined what substances and how much of it are present in the sample. The data collected from the monochromator 32 is processed by the processor 56 and/or stored for later use. The instrument 10 will evaluate the sample for any NIR calibratable, constituent or parameter, using conventional methods as discussed above. In this way, the sample from a given test plot can be thoroughly evaluated.

As opposed to grain, measuring constituents in forage is more difficult. Grain is more homogeneous than forage. Corn forage is comprised of a mixture of kernels, leaves, stalks, cobs, etc. of quite different particle sizes. This makes all of the parameters difficult to read. With forage, there are the additional required steps of grinding (to approximately 1 mm pieces) and drying the samples before sending the samples to a lab. These steps are not necessary with the present invention.

As an alternative to using reflectance to measure constituents of product samples, light could be irradiated through the product samples and sensed after being transmitted through the samples. Also, various geometry's of lamps and sensors could be used. The lamps and sensors could also be separated into two or more components rather than being contained in a single component such as the sensor heads 36 shown in Figure 2. The number of fiber optic strands in each embodiment could also vary greatly. Other types of

radiation other than NIR could be used with the present invention, such as IR. Also, the diffraction grating 38 could be replaced with other elements for spreading the light, such as Fourier Transform, Acousto-Optical Tunable Filter (AOTF).

The preferred embodiment of the present invention has been set forth in the drawings and specification, and although specific terms are employed, these are used in a generic or descriptive sense only and are not used for purposes of limitation. Changes in the form and proportion of parts as well as in the substitution of equivalents are contemplated as circumstances may suggest or render expedient without departing from the spirit and scope of the invention as further defined in the following claims.

What is claimed is:

1. An apparatus for presenting a specimen to an NIR instrument for analysis, comprising: a turntable adapted to be positioned below the NIR instrument; a motor for rotating the turntable; and a first specimen container for holding the specimen and being mountable to the turntable such that the specimen is rotatable beneath the NIR instrument.

2. The apparatus of claim 1 wherein the motor is a variable speed motor.

3. The apparatus of claim 1 wherein the container includes sidewalls to retain the specimen during rotation.

4. The apparatus of claim 1 further comprising a second specimen container interchangeable with the first specimen container, the first and second specimen containers having different dimensions.

5. The apparatus of claim 4 wherein the first and second containers have different depths.

6. The apparatus of claim 5 wherein the first and second containers have different diameters.

7. The apparatus of claim 1 further comprising a microprocessor for analyzing and storing data from the NIR instrument.

8. A method of analyzing an agricultural product sample for characteristics, comprising: placing the sample in a container; rotating the container underneath an NIR instrument; and activating the NIR instrument to generate data regarding the product characteristics.

9. The method of claim 8 further comprising activating a microprocessor to analyze and store the data.

10. The method of claim 8 wherein the sample is rotated for 5-60 seconds.

11. A machine for analyzing characteristics of an agricultural product sample, comprising: an NIR instrument; a turntable positioned underneath the NIR instrument; a container on the turntable for holding the sample; a motor for rotating the turntable and container such that the sample is rotatably presented to the NIR instrument for analysis.

12. The machine of claim 11 further comprising a rack for mounting the NIR instrument, motor and turntable.

13. The machine of claim 11 further comprising a computer for analyzing and storing data from the NIR instrument.

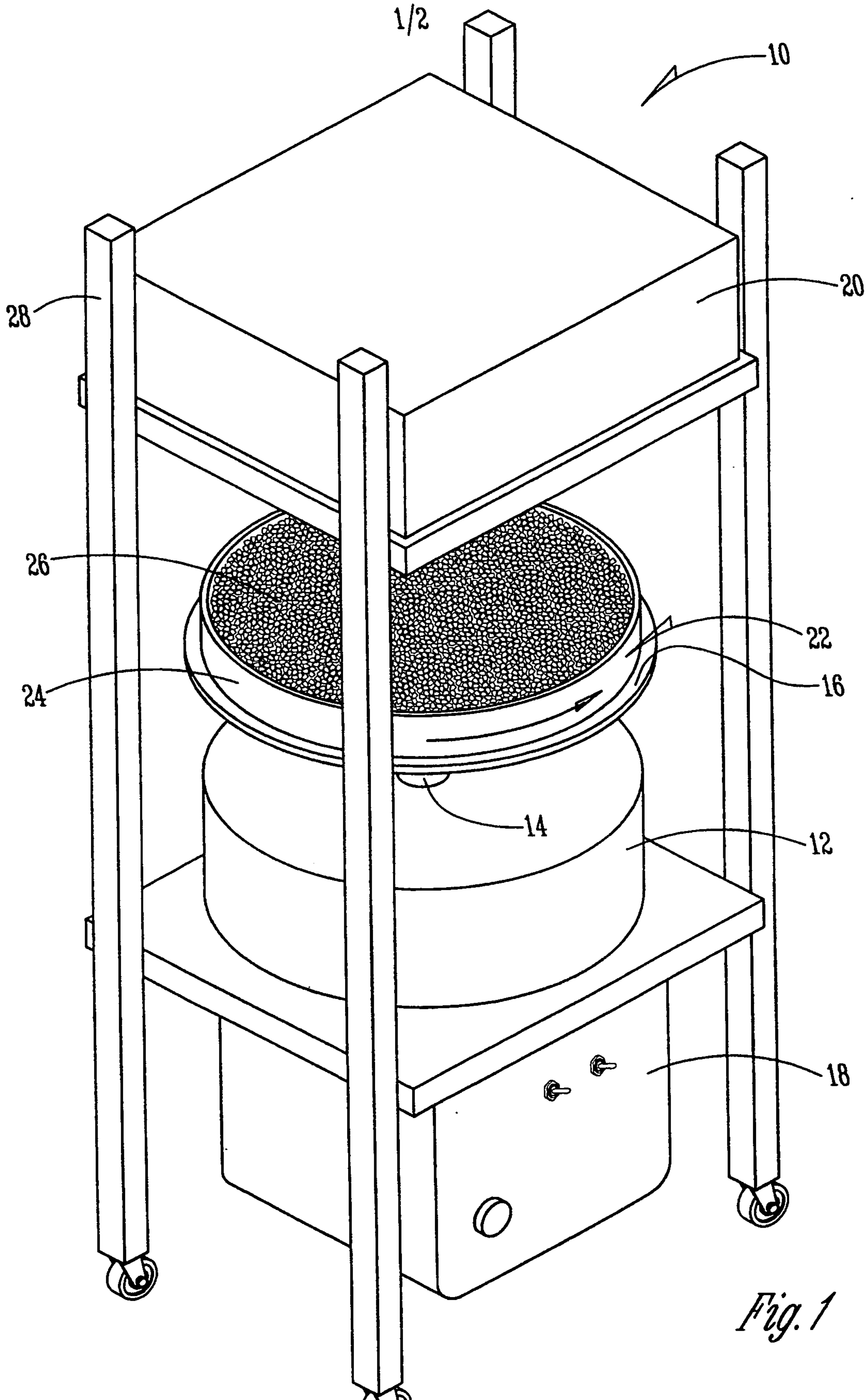

Fig. 1

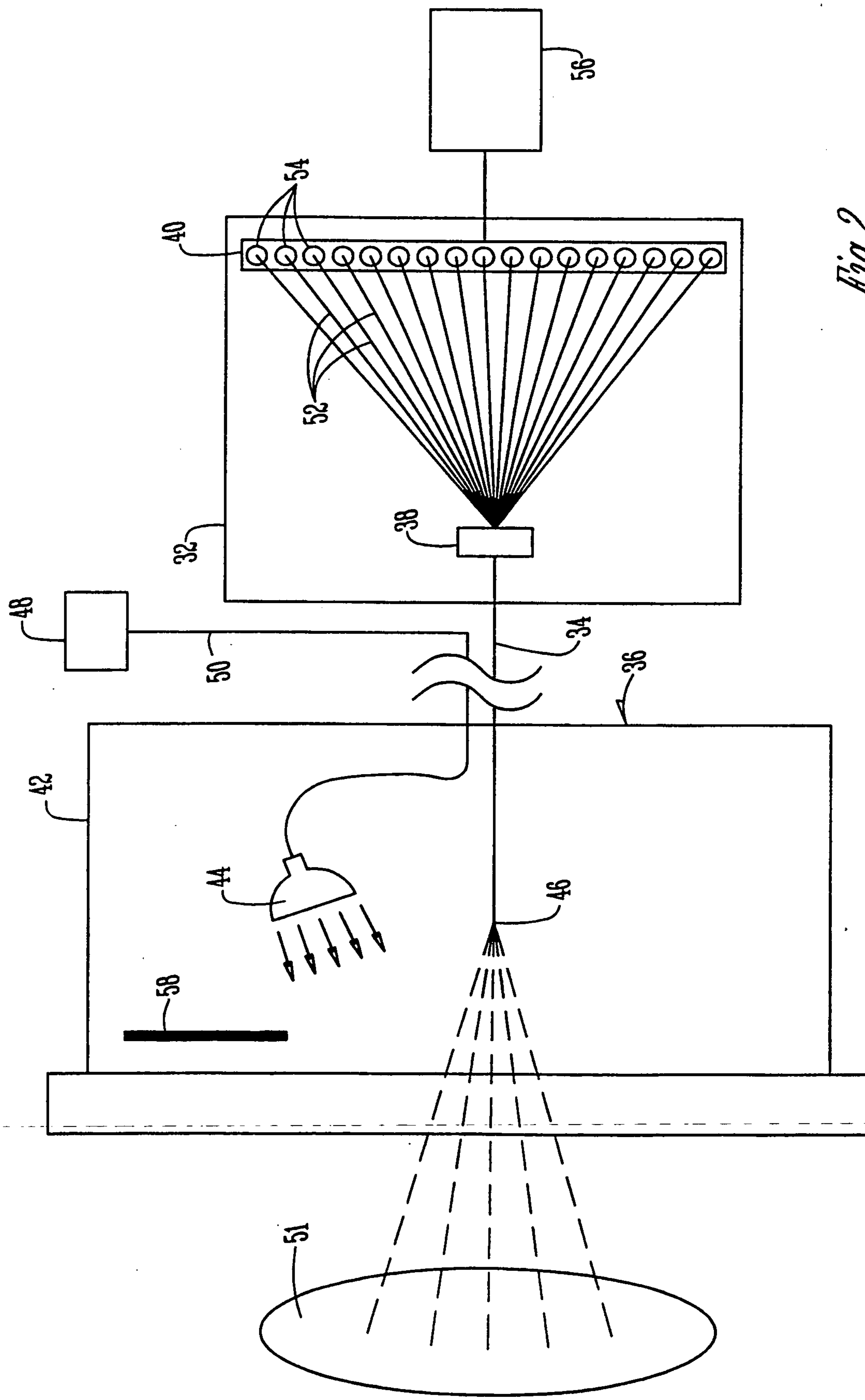

Fig.2

INTERNATIONAL SEARCH REPORT

Inte onal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G01N21/35 G01N21/85

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 G01N

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
E	JP 11 304699 A (KETTO KAGAKU KENKYUSHO KK) 5 November 1999 (1999-11-05) abstract ---	1-13
X	US 5 017 787 A (SATO KIYOMI ET AL) 21 May 1991 (1991-05-21)	1-3,7-10
Y	column 1, line 7 - line 13 column 2, line 3 - line 10 column 2, line 51 - line 56 column 3, line 54 -column 4, line 13 column 6, line 8 - line 21 figures 2,5 --- -/--	5,6, 8-11,13

[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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14 February 2000	03/03/2000

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Inte onal Application No
PCT/US 99/24927

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
Y	US 4 692 620 A (ROSENTHAL ROBERT D) 8 September 1987 (1987-09-08) column 1, line 7 - line 11 column 2, line 28 - line 40 column 4, line 47 - line 66 column 5, line 13 - line 30 ---	5,6
Y	US 4 801 804 A (ROSENTHAL ROBERT D) 31 January 1989 (1989-01-31) column 1, line 23 - line 27 column 1, line 64 -column 2, line 22 column 3, line 22 - line 36 column 4, line 55 -column 5, line 4 figure 1 -----	8-11,13

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INTERNATIONAL SEARCH REPORT

Information on patent family members

Inte ional Application No
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